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THE OCCURRENCE OF *BOTHRIOCEPHALUS LIGULOIDES* LEUCKART, WITH ESPECIAL REFERENCE TO ITS DEVELOPMENT

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This larval cestode was first discovered by P. Manson at the post-mortem examination of a Chinaman at Amoy in 1882, and was described as *Ligula mansoni* by Cobbold in the following year. Since then about fifty-five cases have been reported, mostly from Japan with the exception of a few cases from Africa and the Malay Archipelago. The cases were all reported from the human host and it has been questioned for a long time whether this cestode larva was not confined to the human host. Some authors have suspected the existence of this worm in other animals without having actually proved its occurrence outside of man. A very few writers have described unsatisfactorily and uncertainly the occurrence of the cestode larva in question in animals. For instance, Dr. H. Miyake found twelve specimens of a cestode larva in the muscles of a monkey which had recently died, and he reported his belief that they were the same species as the liguloid larva from the human host, comparing them with the specimens and descriptions of previous authors. But the lack of a precise description for his own specimens prevented their positive identification. Other authors also, viz., A. Hirohata and J. Maejima, have proved experimentally that the larva is able to live and grow in the body of the rabbit by transplanting small pieces of the worm with a scolex into the body cavity of that host.

In 1915, during my animal experiments with the encysted larvae of the lung distome, I accidentally came on August 11 across thirty-six specimens of this larval cestode in the body cavity and body wall of the cat employed in my experiment, which died in an extremely anemic and undernourished condition. Some worms were enclosed by a thin fibrous membrane, while others were lying free in the body cavity or in various tissues of the host. One, two, or even three worms were found in one capsule, and the latter were generally smaller in size than the former. The capsules lay in the muscular or subcutaneous tissues, varying in size and shape. A particularly large number of worms were found in the abdominal and pleural muscular wall, where they were tangled together into a ball or were creeping about here and there.

Some portions of the body wall occupied by the worms had suppurated. This agrees with the suppurating condition which is often reported by various authors for human patients suffering from this cestode larva. Some worms were wound and twisted through various parts of body in such a manner that one end lay in the abdominal cavity and the other end in the abdominal wall, whereas the median portion of the worm lay irregularly in the body cavity and body wall. This state in the body of the host obviously proves the migratory tendency already frequently observed in the human host.

Fresh specimens were extremely mobile, especially in warm physiological salt solution, varying actively the shape and size of body. Large specimens measured 40 to 75 cm. in length and 17 to 20 mm. in breadth. There were also many other specimens in various stages of development or growth. Even in the same individual the length and breadth varies considerably according to the state of contraction. Generally, when it was killed by a fixing agent such as a hot saturate solution of corrosive sublimate, the worm contracted to two-thirds the length of living specimens.

From my own observation of the morphological character and anatomical structure of this worm, as well as its identification by Prof. Dr. Ijima, who was the first writer to describe this cestode larva in Japan, it is evident that the worm in question is the same as Manson's larval cestode of man. Thus I have proved the actual occurrence of this cestode larva in an animal. Furthermore, I am inclined to believe that the normal intermediate host of this tapeworm should not be sought in a human being, but in another animal, though the parasite has not been found previously in the latter host while it has been found so often in the former. Why it seems to occur so often in the human body and so seldom in other animals doubtless depends upon the fact that human parasites are sought more carefully and are hence more frequently found than those of animals. It is obvious that the further development of this cestode larva would be impossible, or less likely at least, if the larvae were normally confined to the human body as a natural intermediate host. I am of the opinion that many animals, domesticated and wild, will be discovered to act as the intermediate host of this larval cestode.

About six months after my discovery, M. Sugimoto in Formosa reported cestode larvae from the pig as *Both. liguloides,* and added that his specimens were quite similar to and probably identical with the specimens of *Sparganum raillieti* Rátz 1913 from the pig. The descriptions of Rátz's and Sugimoto's specimens indicate their likeness. But it is doubtful whether they are identical with Manson's larval tapeworm from man or my specimen from the cat.

As stated above, the great majority of the cases infected with this cestode larva have been reported from Japan. They were found in various districts throughout the country, but especially often near

Osaka, the section where thirty-three out of fifty-five cases (60 per cent) are recorded. Thus I am now in a favorable locality to study the worm in question. Many difficulties, however, are encountered in studying the worm, because it occurs very rarely and consequently is found only accidentally in the human body or in other animals. In spite of efforts by various authors at various times, nothing is known of the life-history of the parasite.

I tried twice animal experiments to determine the final host of this larval cestode. In the first case I used two young cats as hosts and the cestode larva from the cat mentioned above. On August 11, 1915, two larvae were fed to one young cat and one larva to the other. The cats unfortunately died on the 17th of the same month from some unknown cause, and on dissection, no parasites of any kind were found in the alimentary tract.

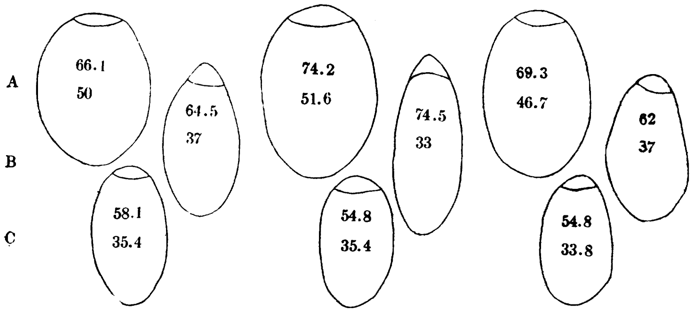
In the second case I made the experiment with the cooperation of my colleague S. Yamada. On June 26, 1916, a specimen of this cestode larva was obtained from a patient who suffered from the worm in the left side of her abdominal wall. The specimen measured 15 cm. in length and 5 mm. in breadth, and was enclosed in a capsule. This larva was given through a catheter to a young dog which was 27 days old, and had been reared in our anatomical department. Before the feeding, the feces of the dog were repeatedly examined for parasite eggs, and we found the eggs of *Dipylidium caninum* only. Afterwards we examined daily for parasite eggs; and on the thirteenth day after experimental feeding we first found a new kind of parasite egg which increased in numbers day after day, and ultimately attained a maximum condition that continued until the animal was killed.

The eggs are elongated oval in shape, tapering toward both poles, markedly sharper at the anterior than at the posterior end. On the anterior pole they are provided with a small operculum. They are mostly symmetrical, the curvature on the two sides of the long axis being unequal. One may find a minute globular thickening of the eggshell at the posterior pole in some eggs, such as is observed in the eggs of certain distomes. The eggs closely resemble those of Dibothriocephalus, but are darker brown in color and different in shape. Some measurements in microns are as follows:

	1	2	3	4	5	6	7	8	9
Length	76.9	75.8	74.5	69.3	68.7	68.5	64.5	64.5	62
Breadth	43.5	37	33	37.1	38.7	36.3	41.9	37	37
Ratio	1.76:1	2.04:1	2.25:1	1.86:1	1.77:1	1.88:1	1.53:1	1.74:1	1.67:1

On August 26, over two months after the feeding, we killed the dog and examined it for the parasites. We found a few specimens of Ancylostomum, two of *Dipylidium caninum*, and one large tapeworm belonging to the genus Dibothriocephalus. This measured 2.5 m. in length and 12 mm. in maximum breadth, the maximum length of proglottis being 2 mm. When alive it was very active and its length and breadth varied considerably, as is usual among cestodes. The posterior extremity showed a bifurcated anomaly, the body being divided into two halves near the median line, one half being 80 mm. long by 5 mm. broad, and the other half 50 mm. long by 3 mm. broad. The length of a proglottis in the bifurcated portion was constant (2 mm.).

From observations on the external features and the internal structure we easily identified this specimen as belonging to the genus Dibothriocephalus, and bearing a close resemblance to *Dib. latus.* But I doubt whether the worm is identical with *Dib. latus* of the dog previously reported. The known species of the genus Dibothriocephalus from the dog are *Dib. fuscus* Krabbe 1886, *Dib. serratus* (Diesing, 1850), *Dib. cordatus* Leuck. 1863, and *Dib. latus* (L. 1748). The worm in question may easily be distinguished from any of the first three species mentioned above.



Eggs of dibothriocephaloid cestodes from the various hosts. × 620.
A. From human host. B. From our dog used in experiment. C. From lion.

I will add a few words on the comparison of this worm with *Dib. latus* which it resembles in some characteristics and not in others. Resemblance exists in respect to scolex form (though not accurately observed on account of irregular distortion by contraction), general form of the strobila, proportion of length and breadth of the proglottis in every part of the strobila, and general structure of internal organs and tissues. A remarkable point of difference is in the shape of the eggs. The eggs of this worm are easily distinguished from those of *Dib. latus* by their shape and the ratio of length to breadth.

The eggs of the new worm are elongated oval in shape and mostly asymmetrical, the curvature on both sides of long axis being unequal, and they taper toward both poles, ending slightly pointed. The anterior pole is more pointed than the posterior, as stated above. The proportion of length to breadth, varying from 1.53:1 to 2.25:1, is greater than that (1.16: 1 to 1.48: 1) of *Dib. latus*. The eggs of *Dib. latus* are oval, both poles ending equally rounded and relatively broader than those of the new worm.

Measurements show that there is a great variation of egg size in *Dib. latus* according to the species of the host, whether human or other animal. The eggs of *Dib. latus* from other animals are the same in shape but much smaller than those from the human host. The next table serves to show the variation of egg size.

	Human 1	Human 2	Human 3	Lion 1	Lion 2	Lion 3
Length	74.2	69.3	66.1	58.1	54.8	54.8
Breadth	51.6	46.7	50	35.4	35.4	33.8
Ratio	1.16:1	1.48:1	1.32:1	1.62:1	1.54:1	1.62:1

From the above tables it is evident that the eggs of the new worm are midway in size between those of the tapeworms from the human host and from the lion.

In spite of such a great difference in the size of eggs, dibothriocephaloid cestodes from human host and other animals have been considered to be the same species as *Dib. latus* by all previous authors. If this identification by the previous authors is unquestionable, the new worm might be identified as *Dib. latus* and the remarkable difference in size and shape of eggs be considered a mere variation among the same species. If this supposition is right, one must reconsider the animal experiment. If the worm obtained from the dog under experimentation is supposed to be *Dib. latus,* the dog must have swallowed a larva of this cestode species; that is, have eaten the raw meat of salmon trout, which is considered in Japan to be the only species of fish harboring the larval form of this cestode. During our experiment the dog was always kept in a cage and fed regularly, so that he never obtained fish as food or accidentally. Before the experiment the dog was nursed by the mother or fed upon remnants of food which were generally boiled or roasted and could not be expected to contain a living larval cestode. Such a careful feeding experiment makes it impossible to think of an accidental infection with *Dib. latus* by food containing the larva. Therefore I am doubtful that the worm is surely identical with *Dib. latus,* and consequently it is a question whether the dibothriocephaloid cestodes from the human host and from other animals have been correctly identified by previous authors.

There is only one remarkable character, the egg size and shape, useful to distinguish positively the worm from the known species, *Dib. latus*. Egg size and shape of parasites, however, is generally assumed to play an important rôle in determining species. Agreeing with this point of view supported by H. B. Ward, A. Looss, and other helminthologists, I have the following opinion in respect to the eggs: I am inclined to believe the worm in question will be experimentally determined hereafter to be the matured form of Manson's larval cestode and quite different from *Dib. latus*. Consequently, some cases — especially from natural infection — of supposed *Dib. latus* from other animals such as the lion, dog, cat, etc., previously reported might have been mistakenly identified and really might have been the mature form of Manson's larval cestode, or indeed of still another species.

The natural mode of infection by *Dib. latus* also seems to support my supposition. To become infected with *Dib. latus,* it is necessary to eat raw fresh meat of fish harboring a larval form of this tapeworm; such fish are the salmon trout in Japan, or pike, salmon, perch, etc., in Europe. Generally the dog is fond of uncooked meat, but not of fish, in Japan at least; so it is unnatural and very rare for dogs to get fresh fish as food. Therefore it is puzzling to me why dogs are infected so often with this tapeworm in Japan, especially in the districts where the fish intermediate host is not found. The same difficulty holds good for the case of the lion, tiger, and other animals which are frequently infected with *Dib. latus,* although these wild beasts are accustomed to eat other weaker beasts and birds, but not fish so far as we know.

It has already been proved, however, by previous authors that the plerocercoid larva of *Dib. latus* from fish can develop to the adult form in the alimentary tract of dog and cat. So it is probable, I think, that the dog and perhaps other beasts like the lion, tiger, etc., can become infected with two kinds of dibothriocephaloid tapeworms, viz., the well-known species *Dib. latus,* and a new species, the adult form of Manson's liguloid larva.

At any rate to have found the adult form of Manson's larval tapeworm is both important and interesting, not only as a contribution to the knowledge of the development of the worm itself, but for the determination of species of dibothriocephaloid cestodes from the human host and from animals.

In closing, I wish to express my appreciation to Prof. Dr. Ijima, Chief of the Zoological Institute, Tokyo Imperial University, for his kind identification of the cestode larvae, and to Prof. Dr. Sakurane, Chief of the Dermatological Department of our hospital, for his courtesy in placing the material at my disposal.